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ABSTRACT

That communication is the engineer's responsibility is inherent in the nature of engineering. The engineer's first order of responsibility is to the organization for which he or she works. Engineers fill specific roles in business, industry, public institutions, and government agencies, and their responsibilities are to get things done for those organizations. The engineer's responsibility, therefore, is to communicate effectively so that these changes occur. The engineer's second order of responsibility is to society, because he or she belongs to a profession whose objective is to improve the conditions of human life by changing the physical environment and systems. Science and technology are considered the basis for the transition to a postindustrial society and for the postindustrial society itself. The engineer will have to communicate effectively to establish and maintain relationships between the sphere of technology and production and the spheres of social services and political institutions. The engineer's responsibility to communicate, therefore, is a commitment the engineer must accept. Those who fail to assume the responsibility to communicate--to interact with the community--ultimately fail in their responsibilities to themselves. (HOD)

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Communication: The Engineer's Responsibility

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"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
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For this series on "Searching for the Engineer's Social Responsibility" I have chosen to talk on "Communication: The Engineer's Responsibility." In my opinion, communication may be the engineer's primary social responsibility, and I choose to address this topic because I do not think that engineers--practicing engineers, engineering educators, and above all engineering students--realize their responsibility for communication. And failing to realize this they may fail to meet their responsibilities as engineers.

That communication is the engineer's responsibility is inherent in the nature of engineering. Of all professions, engineering perhaps is the most "engagée," that is, committed to interacting with society and changing the way we live. Engineering is described as a problem-solving activity, but the types of problems engineers solve are problems in the real world--not the conceptual world of the mathematician, the scientist, the philosopher, the artist. The engineer solves problems of business, industry, public institutions, society--problems of people, of groups of people, and of organizations of people serving people's goals. The engineer solves actual problems (or, to put it another way, addresses needs) that exist to people in the real world. The engineer does not solve problems in "games people play." Thus engineering occurs when the engineer interacts with others to effect change in some aspect of the world around us.

To effect change the engineer must communicate. Therefore communication is the engineer's responsibility. To effect the desired change the engineer must communicate effectively. Therefore effective communication is the engineer's responsibility. The engineer is responsible to the organization he or she serves, to society, and, ultimately, to himself and herself:

1. The engineer is responsible to communicate effectively within the organization.

2. The engineer is responsible to communicate effectively within society.

CS 204 862

3. If the engineer fulfills these responsibilities, the engineer is responsible to himself or herself.

In sum, communication is the engineer's responsibility.

1. The Engineer Is Responsible to Communicate Effectively Within the Organization

The engineer's first order of responsibility is to the organization he or she works for. Engineers fill specific roles in business, industry, public institutions, and government agencies, and their responsibilities are to get things done for those organizations. Contrary to what most engineering students anticipate, getting things done for an organization does not mean doing soils tests, designing a replacement piping system, analyzing a parts failure. Instead it means informing management that the soil can bear the load of vibrating machinery so that the foundation can be poured, presenting a piping design so that inadequate piping can be ripped out and new piping ordered and installed, recommending changes in specifications so that the vendor provides suitable circuit boards. The engineer's responsibility therefore is to communicate effectively so that these changes occur within the organization.

Engineering therefore is a problem-solving process in which communication plays an important role (see Figure 1. The Engineer's Problem Solving Process) [1]. Any organization continues to function routinely, according to schedule, and in terms of assigned responsibilities until persons act to change the existing state of organizational activities. These actions are the end result of a process that is initiated when a need or problem arises within the organization. The problem arises when some person--a manager, a supervisor, an engineer--perceives a disjunction between the existing state of organizational activities and organizational goals and objectives, and decides that this gap must be closed. The gap is seen as a need to improve efficiency, maintain quality, reduce costs, upgrade personnel, return profit, etc. For example, a plant supervisor observes that orders for sheet metal screws continually exceed production line use, at a cost differential of $7,000 a month. An engineer therefore is assigned to analyze the problem, and he or she commences to perform technical tasks to determine a solution. An industrial engineer, for example, will analyze the use of sheet metal screws on the production line and identify where losses occur. The engineer then must evaluate the problem from the perspective of the organization and in view of the results of the technical tasks; the engineer than formulates judgments on how to solve the problem. He or she will conclude, for example, that a trash sorting system to recover dropped and misplaced sheet metal screws would be more cost/effective and acceptable than changing production line operations or installing metal detectors at the time clock. The engineer then must communicate effectively and persuasively to the appropriate

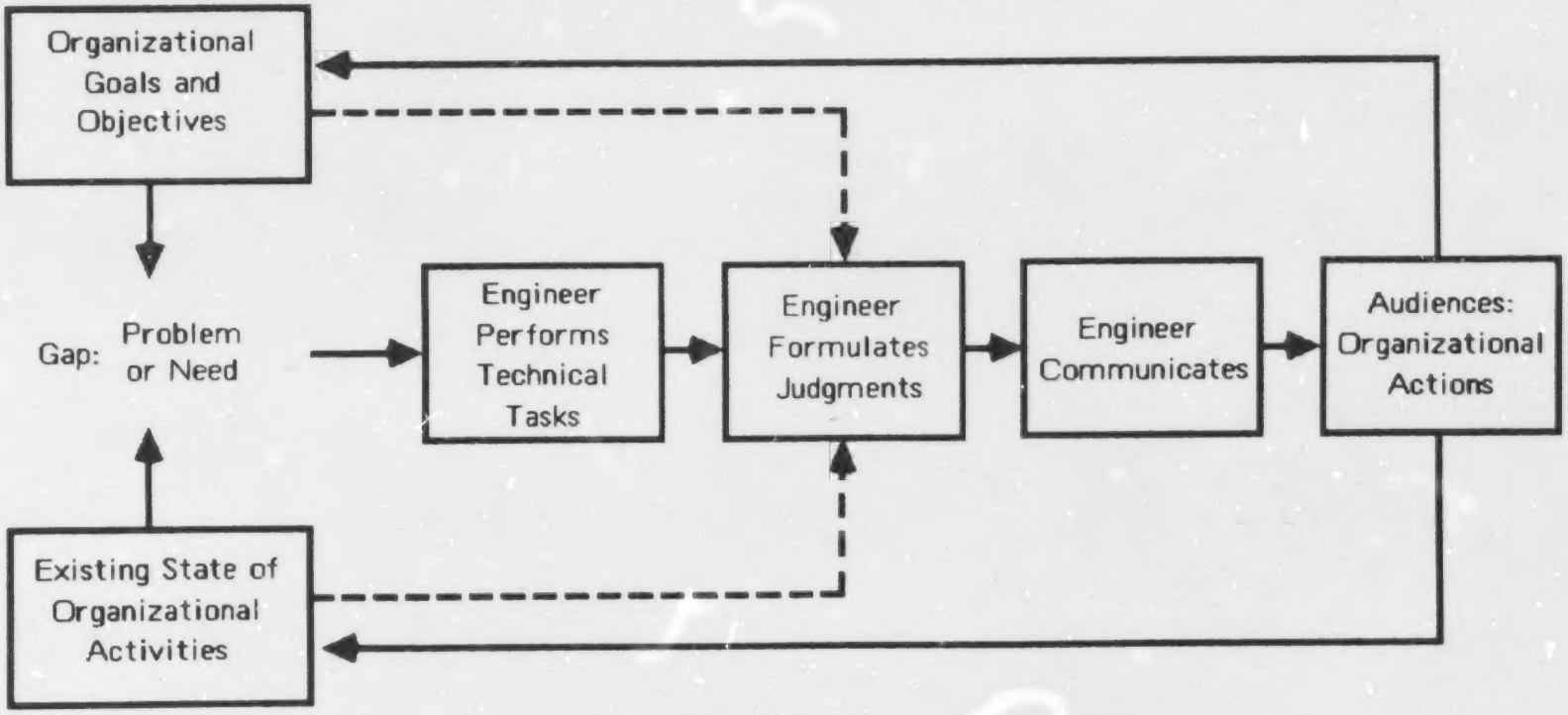

Figure 1. The Engineer's Problem Solving Process.

persons so that they will take the appropriate actions to change the existing state of organizational activities, and perhaps modify organizational goals and objectives. The engineer must get the assistant plant supervisor to authorize a change that can be carried out by maintenance, accepted by the foremen, and approved by the plant supervisor.

The engineer's primary responsibility therefore is to communicate. He or she performs technical tasks in a value-laden context of organizational goals and criteria. His or her judgments have significance only when they are communicated so that appropriate changes occur. Operationally speaking, the engineering is in the communication rather than in the calculations, analysis, design, and evaluation.

A test report by an engineer at a truck proving grounds illustrates the engineer's responsibility to communicate. A vendor had designed a jack to be used with a new truck model. The test engineer's task was to evaluate the jack for selection as standard equipment with the truck. In this situation the engineer found that the jack was difficult to place properly under the axle, and that therefore use of the jack would result in an unacceptable rate of failure. The truck would fall off the jack--posing problems of safety--and the jack would be bent because of improper placement--posing problems of equipment warranty. The test engineer therefore was responsible for writing a test report that would persuade engineering not to accept the jack, and that would enable engineering to request redesign of the jack and to revise performance specifications. An engineer who failed in this responsibility to communicate would cost the company money and, more important, would cost injuries and lives when trucks began to fall off jacks.

An alarming example--in my judgment--of an engineer's failure to fulfill his responsibility--his social responsibility--to communicate effectively is provided by the accident at Three Mile Island. The Presidential Commission investigating the accident at Three Mile Island uncovered a serious "failure" in communication. Memoranda within Babcock and Wilcox during the year prior to the accident had warned that a premature shut-off of emergency cooling pumps could lead to serious problems. The Manager of the Plant Integration Department at Babcock and Wilcox testified about one important memo than informed him that action had not yet been taken although earlier memos "suggest the possibility of uncovering the core if present HPI [high pressure injection] policy is continued." He said, concerning this important memo, that "I recall glancing over it very quickly and keying on the two specific questions. I do not recall reading it very carefully at the time.... I remember thinking that they were rather routine questions.... I then, just that quickly, disposed of this piece of paper crossing my desk" [2]. In Plant Integration the existing state of organizational activities continued unchanged--it was business as usual. Had the manager acted in response to this memo, the accident at Three Mile Island might well have been

prevented. His failure to respond suggests that the engineer who wrote the memo did not assume his responsibility to communicate effectively. In effect, that engineer did not communicate at all--unless one considers filling the circular file communication.

The engineer's first order of responsibility is to communicate effectively within the organization he or she works for. And this is a social responsibility because the organization is part of society, and the goals of that organization are sanctioned by society and therefore are part of society's goals. Whatever mix of profit, safety, livelihood, technical usefulness, and personal service forms the goal of an organization also forms an acceptable subset of society's goals and of goals of groups of persons within society. Thus to communicate effectively with the organization one works for is to fulfill a social responsibility.

2. The Engineer is Responsible to Communicate Effectively Within Society

The engineer's second order of responsibility is to society. Engineering is a profession as well as a career, so more than responsibility to an organization is involved in engineering. The engineer has responsibilities to society in addition to those he or she has to an organization. The engineer fulfills his or her social responsibilities, not only by fulfilling his or her organizational responsibilities, but by filling his or her responsibilities as a professional. The engineer is a member of a profession that has been intrinsic to the development of Western, American, and Canadian cultures, and that has helped create the goals and visions of those cultures. The engineer therefore has a responsibility to communicate with his or her society so that his or her engineering activities effectively contribute to the advancement of social goals.

The engineer has social responsibility because he or she belongs to a profession whose objective is to improve the conditions of human life by changing the physical environment and systems of human life. The engineer has fueled the dramatic technological progress that has enabled people as individuals to live more rewarding lives. My father, for example, was a civil engineer who took great pride in the social value of his work. He designed low head dams to control floods and improve water supplies. He designed magnesium structures for aircraft during World War II, both to preserve democracy and to advance the airplane industry and improve commercial travel. The industrial engineer improves health care delivery systems; the mechanical engineer improves heating and cooling systems; the chemical engineer improves the quality of our homes and materials; the computer engineer improves the efficiency of our factories, businesses, and public institutions. Although any engineer, of course, is in a career to earn a living, he or she is in a profession whose mission is to serve society and the institutions

of our society. The engineer has this social responsibility.

The engineer, however, should not take this responsibility for granted. The engineer has the responsibility to communicate with society--with persons and institutions of our society. In order to do engineering, engineers interact with the worlds around them. Engineering, as I've said, changes the physical environment of human life, so engineering involves tradeoffs among different and conflicting values in our society and among different and conflicting goals of our institutions. The engineer therefore has a responsibility to communicate with society so that the changes he or she creates are as beneficial and acceptable as possible. Just as the engineer in an organization has responsibility to ensure that effective actions are taken to address organizational problems, the engineer has a professional responsibility in society to ensure that the changes his or her engineering creates are appropriate and indeed change the existing state of the physical environment in ways that effectively narrow the gap between our desires and visions and the existing conditions of our lives. The engineer furthermore has a professional responsibility to evaluate the appropriateness of our desires and visions insofar as these relate to engineering economics, technical tradeoffs, and social feasibility. The engineer therefore must communicate with persons and institutions of our society--and must communicate in a truly transactional sense. Communication as a social responsibility requires listening and talking, disagreeing and agreeing, adapting and accepting, demonstrating and doing, cooperating and leading. In sum, the engineer as a professional in society helps us all to make tradeoffs and to optimize the physical and ultimately social changes he or she creates.

The engineer's social responsibility to communicate in one sense has been a recent development. Historically the engineer's concept of social responsibility has been founded on our unquestioned faith in technology and progress. As a profession engineering matured in a society that did not seriously question technological progress. By becoming an engineer a person automatically became socially responsible. The engineer had not the additional social responsibility to communicate because both the engineer and society assumed that the changes created by the engineer had intrinsic worth.

As we have become aware of the mixed blessings of unfettered technological progress, however, the engineer has acquired the social responsibility to communicate. The engineer is at the interface between technology and society, between industry and the public, between the government and its citizens insofar as considerations of our physical environment and our man-machine-institution managed processes and systems go. The engineer is the change agent who will effect the transition to a post-industrial society, and will determine the form of the future. This role requires above all that the engineer communicate.

The role of the engineer and the communication

responsibilities of the engineer are illustrated by an engineering project I was associated with several years ago. The project provides a microcosm of the collective actions of engineers and engineering, and indeed of the development of the world we know today.

A group of engineers headed by an American engineer recommended a series of dams along a river in a third world region. The river, they observed, has impressive potentialities for multi-purpose development, which would significantly raise the standard of living of the people involved because of agricultural benefits, industrialization, flood control, health benefits, transportation improvements, energy production for commercial and domestic use, etc., the dams would provide--benefits which justify the engineer and engineering. However, the developmental process does not provide an unmixed blessing, and illustrates the need for the engineer to be aware and to communicate.

In general, the project envisions the formation and evolution of large urban settlements in a river basin region which now is predominately rural. It will transform the lives of the people affected and the forms of governmental administration. Initially, a half-million people will be displaced by the dams. The displacement is a first but minor societal impact of the project.

As the first major benefit, the project envisions significant development in the agricultural sector. Such development will necessitate an agricultural extension service, with a minimum of 2000 extension employees to be trained. The service will require transportation and information networks to be established. Then, it will require a network of demonstration farms, 1 for each 100 farms, to teach the new agricultural techniques. These involve the use of fertilizers, insecticides, seeds, and implements, which will have to be manufactured or imported, transported, and distributed. These processes will require institution of a marketing/economic infrastructure. Thus, a development center will be required for each village of 100 farmers, who will need capital to buy the materials and to build farm buildings to store the materials. Buying will require the introduction of short-term credit into the social system; building will require a secondary economic network of materials, techniques, and personnel.

These actions will greatly expand agricultural production, which in turn will create marketing needs. A farm-to-market road network will be developed, and storage and processing facilities will be required. To maximize agricultural production will require farmers in a locality to produce similar crops for the market and to cooperate in arranging transportation. Thus, multi-purpose cooperatives and credit institutions will be needed--one for each 500 farmers. A national federation of cooperatives is envisioned to give them political visibility and power. To establish the needed 3500 cooperatives a massive

education campaign will teach cooperative principles, management, and techniques to the farmers.

On a national level this agricultural development will require land reform, because there is a strong correlation between agricultural productivity and security of land tenure. Thus, an administrative bureaucracy will be needed to organize land titles and transfers. Also, the agricultural development will require new policies and programs to increase and manage grain output to respond to fluctuations in export demand. Diversification of crops will be required, for example, and long-term trade agreements negotiated. Tax structures will need to be devised, as well as subsidy structures to meet export requirements. Irrigation policies will be needed to control the use of water for maximum benefit.

In addition to grain production, the agricultural development will include a significant expansion of livestock production. Such expansion will require a parallel set of actions, from extension service activities to tax structures and land use controls. Furthermore, the engineering project will lead to similar actions in the forestry and fishery sectors. Finally, as its second major benefit the project will enable extensive industrial development, which perhaps will require even more complex and sophisticated socio-economic infrastructures than will the agricultural development. The project ultimately is envisioned to create a complex urbanized society.

Thus, the engineering project will require the planned development of urban societies, evolving around regional development centers. The government will have to control the numbers and locations of these urban centers. It must develop and manage resettlement, public health, manpower, and many other societal institutions. In 30 years it will have to develop a cadre of perhaps 400,000 skilled workers, from mechanics to chemists to salesmen to administrators. This extensive development will require the close cooperation between education administrators and the national policy makers. This development will require control of the migration of skilled workers, who gravitate toward urban centers. It will require regional cooperation and tele-communication networks. In sum, the engineering project will occasion the development of a complex nationally organized socio-political system that will require bureaucratic management of almost aspect of the social lives of the people and affect almost every aspect of the private lives of the people.

I have just described a project being undertaken by many engineers that will transform a relatively underdeveloped society into the industrialized urban society that we have in the Western world. Lest engineers not rest on these laurels, in the Western world they must realize they are in the process of creating a post-industrial society. Kenneth Boulding asserts that mankind in the short span of the twentieth century is undergoing a transition as profound as the transition from precivilized to

civilized society initiated somewhere past five thousand years ago. This second "great transition involves changes in moral, religious, and aesthetic aspects of life just as much as it involves changes in our knowledge and use of the physical world. It involves, for instance, change in the nature of the family and in the patterns of child rearing" [3]. Scientific and technological development is having such a profound impact on modern society that social institutions, cultural values, and personal life styles are being radically and irrevocably changed. The engineer, consciously and unconsciously, is the architect of this totally new civilization.

Science and technology are considered the basis for the transition to a post-industrial society and for the post-industrial society itself. Their methods and products effect social change, and the value systems and world views associated with science and technology encourage change and development. The post-civilized society being created has been characterized by many commentators, and the characteristics of a "post-industrial" society are envisioned to include a complex technological infrastructure, a highly developed service sector infrastructure, a complex centralized hierarchy of social institutions, and global interdependencies [4]. The engineer may have an even more responsible role in such a society than the engineer has today.

The need for the engineer to communicate in such a society and to ensure an effective transition to such a society cannot be questioned. The engineer will have to communicate effectively to establish and maintain viable relationships between the spheres of technology and production and the spheres of social services and political institutions. The dockets for the licensing procedures to construct and operate a nuclear energy facility are replete with innumerable types of communication between and within industries, government agencies, public interest groups, and private citizens, and engineers play a central communication role in the interactions among these groups. Suffice it to say that the role nuclear energy will play in the future to a significant extent depends on the engineer and <u>how</u> the engineer fulfills his or her communication responsibilities. A consulting engineer recommending a solid waste disposal and energy producing facility to a city council is mediating between city and county jurisdictions and goals, between traffic and sanitary waste collection departments, between city council representatives from different constituencies, between the citizens who will live next to the facility and the others who will be served by the facility, between environmental activist groups and private rubbish contractors. Whether it is built and how socially acceptable, efficient, and beneficial it will be to a considerable degree depends on how the engineer fulfills his responsibility to communicate. An engineer writing a test report on the safety of a gas tank design for an automobile model has the public and the courts as well as his supervisor looking over his shoulder, and has the responsibility to communicate effectively in the interests of his company, in the interests of

his profession, and in the interests of his family and the public at large--and these interests no longer are clear or mutually compatible.

John Platt discusses the dangers inherent in the world we live in and in the transformation of our society into a post-industrial society. He in particular discusses the dangers inherent in "certain self-reinforcing 'lock-in situations' which represent the most dangerous situations in the world today" [5]. In agricultural engineering, for example, the relevant agricultural, industrial, political, economic, and social institutions are locked into the production and use of fertilizers and pesticides--chemical engineering accomplishments of mixed blessings today and for the future. In order to help us break out of these lock-in situations which he was instrumental in creating and in which he performs professionally, the chemical engineer must communicate not only within a chemical company, but within society as well. He must help others in society change their desires and goals as well as modify existing states of affairs, and he must be sensitive to the relationships between the objectives and goals of the company he works for and those of the social institutions and society at large of which the company, his profession, and he himself partake.

In sum, in order to integrate his actions effectively as an engineer with his organization and with social institutions and society at large, the engineer must develop an awareness of the social problem solving process and of his responsibility for effective communication within it. He must communicate as an employee, a professional, a citizen, a member of a community, and a private self. This is a heavy social responsibility indeed.

3. If the engineer fulfills these responsibilities, the engineer is responsible to himself or herself

The engineer's responsibility to communicate therefore is a commitment the engineer must accept as a person. The individual has a responsibility for everything he or she does and for the effects that his or her actions cause. These actions necessarily involve other persons, and so the engineer must assume the responsibility for communicating with other persons. Engineering societally is a mutual enterprise, not a private enterprise. A person assumes this commitment when he or she becomes an engineer and joins the profession of engineering.

Every engineer assumes the responsibility of affecting the lives of other people, and the engineer must accept the communication imperative involved. The engineer who designs the fuel system for an automobile in some small way conditions the way we drive, the energy we use, our attitude toward automobiles. The engineer also contributes to our safety and welfare, and in the case of an automobile accident assumes a share of the responsibility along with other automotive engineers, management, mechanics, the highway engineers, the drivers, the public, etc.

Through communication the engineer shares this responsibility, and helps us all move toward our evolving social goals.

Engineers who fail to assume the responsibility to communicate--to interact with the community--ultimately fail in their responsibilities to themselves as persons. The engineer who communicates fundamentally is responsible, not only as an engineer and not only as an employee, but as a person.

Communication is the engineer's responsibility.

References

1. The communication process is explained in detail in J. C. Mathes and D. W. Stevenson, Designing Technical Reports (Indianapolis: Bobbs-Merrill, 1976). See especially Chapters 1, 2 and 3.

2. This testimony and other relevant testimony and memoranda are in Transcript of Proceedings, President's Commission on the Accident at Three Mile Island, Public Hearing, July 18-20, 1979. Quotes: July 19, pp. 240-241.

3. Kenneth Boulding, The Meaning of the Twentieth Century (New York: Harper and Row, 1964), p. 13.

4. Daniel Bell, ed., Toward the Year 2000: Work in Progress (Boston: Beacon, 1969), pp. 1-8.

5. John Platt, "Shaping the Evolutionary Future," Perception and Change (Ann Arbor: University of Michigan Press, 1970), pp. 142-148.

Note: I have drawn upon several of my previous publications for some of my material: "The Engineer's Social Responsibility as Personal Commitment" (Phi Kappa Phi Journal, 50:2, 1971, 6-12); "The Engineer As Social Radical" (The Ecologist, 5:4, 1975, 119-125 and Mines Magazine, 68:1, 1978, 7-8, 30-33); "Value Oriented Social Decision Analysis" (IEEE Transactions on Systems, Man, and Cybernetics, 9:9, 1979, 567-580). Figure 1 is adapted from "Technical Communication: The Persuasive Purpose" (English in Texas, 11:4, 1980, 81-83).